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ABSTRACT

This paper discusses the classroom, home, and distance use of new, flexible, interactive, application-oriented software known as Active Learning Suite. The actual use of the software, not just a controlled experiment, is reported on. Designed for the e-learning of university mathematics, the program was developed by a joint U.S.-Russia team and was funded in large part by the National Science Foundation (NSF). Attention is directed to the fact that this integrated mathematics curriculum software has a multi-level structure and a flexible format to allow for a personalized pace of learning and to accommodate students with poor backgrounds, those with some knowledge, and those who are more advanced. The program may be used in classrooms equipped with stand-alone computers, a local network, or over the Internet for distance learning. A major goal of the project is to help students reach a better understanding of concepts, parameters, and mathematical tools as well as learn how to apply a systematic approach to everyday problems and situations. The paper discusses the state-of-the-art graphics and interactive lessons, which are designed to stimulate each student's involvement in his or her own learning at the appropriate level and pace. A sample lesson, the effects on performance and learning, and the reactions of faculty and students, both local and distant, are included. (Author/KHR)

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The Use of Flexible, Interactive, Situation-Focused Software for the E-Learning of Mathematics

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ABSTRACT. This paper discusses the classroom, home, and distance use of new, flexible, interactive, application-oriented software, known as Active Learning Suite. This paper serves as a report of the use of the software and not of a controlled experiment. Designed for the e-learning of university mathematics, the program was developed by a joint US-Russia team, and was funded in large part by the National Science Foundation. Attention is directed in the paper to the fact that this integrated mathematics curriculum software has multi-level structure and flexible format to allow a personalized pace of learning and to accommodate students with poor backgrounds, those with some knowledge, and those who are more advanced. The paper details that the program may be used in classrooms equipped with stand-alone computers, a local network, or over the Internet for distance learning. A major goal of the project is to help students reach a better understanding of concepts, parameters, and mathematical tools, as well as to learn how to apply a systematic approach to everyday problems and situations. The paper discusses the state of the art graphics and interactive lessons, which are designed to stimulate each student's involvement in his/her own learning, at the appropriate level and pace. A sample lesson, the effects on performance and learning, and the reactions of faculty and students, both local and distant, are included.

Mathematics Subject Classification (1991): 00A35

1. Introduction. Developed under the leadership of Dr.Yakov Cherner of AteL (Advanced Tools for e-Learning), Active Learning Suite (ALS) introduces mathematical and scientific concepts through pedagogically sound computer-based activities and simulations associated with real-world situations. A major goal of the project is to help students reach a better understanding of mathematical concepts, parameters, and tools, as well as to learn how to apply a systematic approach to every-day problems and situations. The software naturally and visually bridges mathematics, science, and technology-based education. Active Learning Suite is different from more traditional educational software in that it allows students to engage in the study of familiar real-world systems, including the interconnections existing between various system components. The program uses real-life situations, such as those related to plumbing, wiring, golf, telecommunications, human circulatory system, kitchens, et cetera, as the context for investigations. This enables the users to discover the connections between theory and the practical applications in technology.

A main goal of ALS is to improve the teaching and learning of mathematics and science in conjunction with advanced technology. The aim is to engage students in the learning process and replace passive learning modes with active modes. The software is designed to assist students in exploring physical concepts and laws based on application-oriented contextualized learning situations and therefore link mathematics and science content and technology education around real-life technical problems. The vital link of physical concepts with real-life experiences and career goals fosters the students' perception that mathematics and science classes, such as calculus, applied mathematics, and physics, provide them with useful knowledge. The software provides the framework for integration of various educational resources available from different sources including the Web. [1] This paper reports on the use of the software by the writer and his students and does not purport to be a controlled experiment.

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2. Pedagogical Strategies and Software Features. Many educators believe that students are better at learning concepts if they have experience with the concrete phenomena that are being studied and if they are aware of the potential applications of the knowledge they are acquiring. It is further believed by many educators, that learning mathematics using inquiry-based activities, visualization, and virtual experimentation in the context of real-world situations can help to foster the learner's confidence to ask questions, test hypotheses, and contribute ideas to the group. ALS subscribes to and is built upon these beliefs.

Although use of a non-traditional pedagogical approach is recommended, the proposed software can also be used as part of more conventional teaching and learning strategies. In the learning cycle based on this software, visualization, modeling, and visual experimentation help students build up their qualitative understanding before mastering quantitative principles.

In contrast to the conventional linear teaching strategy that follows the topics and laboratories in a standard textbook, the proposed learning cycle first engages the students in a familiar real-life situation. Only then, in the context of this situation, are relevant mathematics and science concepts and laws explored and studied. While doing this, the teacher demonstrates how knowledge of fundamental mathematics can be applied to achieve a better result in solving specific technical problems.

The project materials actively facilitate interactive group learning and occupation-oriented role games. This helps the instructor to create an inquiry-based atmosphere in the classroom and brings a competitive element of excitement to the learning process.

The instructor can require students to use the software to do some computer-based experiments or problem solving outside of the classroom. In this way, in-class time can be traded for outside-of-class time, thus freeing up classroom time for activities that utilize the instructor most effectively. In addition, out-of-class exploration activities prior to classroom discussion help to prepare students mentally to accept ideas during the follow up lesson. To efficiently understand a new concept, students have to think about the concept before formal study begins. [3]

The contextual links created between the curriculum and the students' expectations and career paths allow the instructor to maintain student interest. Students can work in groups to use the software. In doing so, they have the opportunity to explain their thoughts and predictions to their peers. Effective peer instruction promotes collaboration within teams and competition between teams. [4]

The teacher can prepare different tasks for different students depending upon their grasp of the concepts and their backgrounds. In this case, not only the number and level of tasks but also the pace of learning can be personalized. This is an innovative way to solve a classroom management problem; namely that students work and learn at different rates, no matter how homogeneously they are grouped.

The program may be integrated into existing courses and can help instructors seamlessly move from a conventional lesson format to a more innovative teaching technique. The networking version will bring an additional flavor to the software features. Because virtually everything in Active Learning Suite can be controlled from a script, the teacher can, from his/her computer, completely manipulate a remote student's computer in real time.

Although the software is divided into individual sections, which may be used independently if desired, it is best to be used as an orchestrated whole. Rather than a set of detached educational components, Active Learning Suite is a single, comprehensive, multi-purpose and multi-functional system, which is an end-to-end e-learning solution. The architecture is designed for interoperability and compatibility with major learning platforms and software

packages. It offers adaptive assessment and tracking systems and networking options. Commercial uses in non-academic areas are included for corporate training. In addition, all or part of Active Learning Suite is in use in the United States, Russia, Germany, Poland, and France, making it truly international. [1] [5]

3. **Classrooms.** Classrooms can be set up with a single computer and display screen, a few computers that teams may work around, or an entire classroom of computers in which each student has his/her own. The teacher can structure the presentation and use of the materials according to the available technology. In many cases students have their own computers and usually have access to the Internet. In these cases, students can spend most of their software-usage time outside class, and the instructor can use class time for large idea presentations or special student-based presentations to the group. In classes with numerous computers, groups or individuals can use the software in class while the instructor acts as a resource and a facilitator. The more time students spend using the program, whether in class or outside of class, the greater the benefit they will receive from it. It is up to the instructor to budget the time and usage that he/she feels will best serve the students.

4. **Distance Learning.** In recent years, many higher educational institutions have developed strong distance learning courses and degree programs. Companies also have converted traditional training into distance learning. Active Learning Suite uses its proprietary software tools and technology to help both institutions and corporate training departments enter the world of e-learning by creating an on-line content authoring, delivery and management system to use for both digital surrounds of classroom based courses and fully on-line offerings. The options include real-time classrooms, self-paced or asynchronous learning, and collaborative learning through the use of e-mail, chat, instant messaging, and active voice communication. The use of the Internet makes it all possible, practical, and adventurous. [1]

5. **How Active Learning Suite Will Be Used By Students.** The timeline for students may vary from one to several hours per module. The same module can be used several times because each module covers more than a single topic. For example, the electrical kitchen stove module illustrates topics from electricity such as resistance and Joule's law, and then when a pot of water is placed on the stove, heat and water-vapor phase transitions can also be considered. Much depends on the education level of the students and their teacher's preferences and style. All or some of the component modules can be used separately if desired.

Materials can be used during a lecture for virtual experiments, as an Interactive Demonstration or to complement part of a laboratory experience. The materials can also be used by a growing number of students who have computers at home. The Interactive Lessons and Problem Solving Tutor may be used both in class and at home. The network version opens new horizons for distance learning and teaching, particularly for adult students and people with disabilities. [2]

6. **Sample Lesson.** A classroom instructor may first present any relevant material to students in traditional lesson format, but ALS is designed so that such presentation is not necessary. Being a traditionalist but also being open-minded, the instructor (writer) tried each format. It was felt that initially one method did not out-weigh the other in its effect on student performance. However, after a few sessions, students were so anxious to work with the software lessons that the "instruction first" method only caused frustration and lack of attentiveness. Students preferred to ask questions on an "as needed" basis. It is recommended that each instructor similarly try each method until a level of comfort with one method or the other or a combination of the two is determined. This may vary according to the learning needs and styles of the students in each class and the comfort level of the instructor.

ALS uses a combination of computer voice, on-screen text, graph, table, and visual animated simulation on each screen of each lesson. Students are presented a topic and background information. A demonstration is provided in which the relationship and interaction of the parameters is discussed and viewed on-screen. Students are asked to change various parameters and examine the results these changes have on the tables, graphs, and animated simulations. They are then able to make conjectures and explore these through further on-screen manipulation of variable conditions and parameter values.

One such lesson examines and simulates heat transfer through a wall of a house. The student can preset the type of material in the wall, the thickness of the wall, the temperature inside the house, and the temperature outdoors. Through on-screen simulations, the student can observe the effects, both physical and graphical, of changing various parameters. The student may first use the "autoexplore" options in which the software runs a short demonstration of each change of parameter. He/she may then make predictions as to how changing certain parameters or combinations of parameters will affect the situation. The student may immediately test those predictions and observe the simulated results on-screen. For example, the student may change the thickness of the wall to see if it slows down the transfer of heat or he/she may try a different wall material to see if it increases or decreases the rate and amount of heat transference. If the student changes the inside or outside temperature, the animated picture changes to reflect the conditions, climate, or even the season. The combination of simulated and graphical resultant changes on-screen is designed to help the student observe the effects of his/her changes immediately and provides a strong and essential visual link between mathematics and real world effects.

In the heat transfer lesson, students interpret graphs through the on-screen plotting in "real time" of the resultant behavior of each altered condition. The functions are invariably on more than one variable. Through on-screen observations, students have the opportunity to explore how changes in one variable can affect the others without the tedium and drudgery of countless recalculations by hand. Rate of change is used in this lesson by discovering how factors, such as wall material, wall thickness, change in inside temperature, and change in outside temperature, affect the amount and rate of heat exchanged through the wall.

7. Student Results and Feedback. Through interviews, daily discussions, and many large group discussions, seventeen students in Calculus I have provided feedback on their use of the Active Learning Suite software. The classroom was configured with a teacher's computer work and demonstration station and two student computer work stations, all three of which were on the local network and all three of which had independent access to the Internet. There was a computer lab available in a nearby room with twenty-four more student workstations (identical to the two in the classroom) for use by the class whenever desired. Each of the seventeen students had a home computer and access to the Internet. The software was used as an integral part of the course and not merely as an amusing supplement. The students reported that they enjoyed the hands-on approach to calculus and found the real-life applications and interactive graphics extremely helpful. Ten of the students were computer literate and adept in the use of graphing calculators, so their transition to the software of the Active Learning Suite was easy. The other seven students showed brief trepidation at the prospect of using the software to learn their mathematics, but they later reported in interviews quickly overcoming their fears when they began to enjoy the interactive and flexible nature of the program.

The program was also used by five other students as a distance learning project. They did all of their work at home through e-mail and chats and direct connection to the software packages. The amount of e-mail and the excitement illustrated during the chats illustrated how much the program was employed and enjoyed. According to student feedback during interviews and group meetings, chats and the interaction with the actual software components offset the disadvantage of not being in class for the interaction of classroom discussions. The

students not only e-mailed and chatted with their instructor, they e-mailed and chatted with each other about the lessons. Active Learning Suite offered these students immediate feedback and constant interaction, rather than a time delay waiting for a response to what was just done or tried. Each student involved, in-class and distant, reported a sense of improved problem solving skills and an increase in the desire to spend time doing mathematics.

8. Results of Other Students Who Tried the Software Without Direction. Twenty students in a programming class volunteered to be what they thought were Beta-testers of the software. They had a wide variety of backgrounds and abilities in mathematics, science, and technology. They were as heterogeneous a group as one might expect, except for the fact that they all enjoyed programming and were anxious to be Beta-testers. After four months of independent experimenting, these students reported individually through email and interview that they enjoyed the software, thought it a wonderful way to learn, and wanted to know how to enroll in courses which were planning to use the software. They were then brought together to discuss their results as a group. The discussion never once turned negative. The excitement and interest generated by the program was overwhelming. Even those students with limited backgrounds or abilities in mathematics and science reported individually and in the group that they found the lessons informative and fun and felt they benefited from them.

9. Reaction of Faculty. The feedback from other ALS instructors, through interview and discussion, was enthusiastically positive. They reportedly enjoyed the heightened interest of their students and welcomed the program as a stimulant to their own interest in the material. The ability to see, from more than one perspective, the immediate result of changing one or more parameters in a problem was a major plus cited by all. Most admitted that they spent their spare time experimenting with various scenarios of the software for their own enrichment, as much or more than for class preparation. The instructors were pleased that the e-mail they received from their students regarding assigned problems was constructive and inquisitive rather than desperate.

10. Summary of Points One through Nine. As discussed, Active Learning Suite in an application-oriented, integrated curriculum software package for mathematics, science, engineering, and technology education. The program employs a situation-based approach rather than a conventional domain-centered approach to involve students of various backgrounds and abilities in their own learning. The goal is to engage students in exploring learning situations associated with the real world and their career objectives. Open-ended software, assessment tools, interactive lessons, problem solving tutorials, and simulation modules of real-life situations allow students to actively participate in modeling and virtual experimentation and to observe the physical processes from macroscopic to microscopic levels. Tools are provided that enable teachers to assemble a computer-based learning environment from heterogeneous sources and the Internet. The software can be used in classrooms equipped with stand-alone computers, a local network, or over the Internet for distance learning.

Among many in the educational community, there is currently an emphasis on providing multiple representations of problem solutions and a realization that various learning styles require a variety of presentation techniques. ALS's combination of computer voice, on-screen text, table, graph, visual animated simulation, and emphasis on conjecture and experimentation addresses these issues.

The materials are designed for a wide audience including: students majoring in mathematics or science or engineering or technology; those students not majoring in these areas but seeking literacy in these areas in anticipation of workplace demands; two-year college students enrolled in mathematics, science, engineering, or technology; and high school students taking calculus or physics or those involved in career preparation programs. The software has a multi-level structure and flexible format to accommodate students with poor

mathematics and science backgrounds, those with some knowledge, and those with advanced knowledge.

Active Learning Suite's on-line teaching and learning system emphasizes problem-based learning. It is designed to challenge learners to develop effective problem-solving strategies and critical thinking skills. This enables the learner to discover the connections between theory and practical application. The program provides instructional opportunities on campus, at home, in a corporate setting, or through distance learning. [1]

The instructor (writer) discussed in this paper is extremely pleased with the results of ALS within his classes and is excited about continuing its use in the future.

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